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1. Your reference	IP/P7056	
2. Patent application number *(The Patent Office will fill in this part)*	0314934.1	26 JUN 2003
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	QINETIQ LIMITED Registered Office 85 Buckingham Gate London SW1E 6PD United Kingdom	
Patents ADP number *(if you know it)*	8183857005	
If the applicant is a corporate body, give the country/state of its incorporation	GB	
4. Title of the invention	Safety Helmets	
5. Name of your agent *(if you have one)*	Christopher Michael Farrar	
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	QINETIQ LIMITED IP Formalities A4 Bldg Cody Technology Park Ively Road Farnborough Hants GU14 0LX United Kingdom	8183873001
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Description 19 psm

Claim(s) ~~6~~ 5

Abstract 1 only

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

Request for preliminary examination and search *(Patents Form 9/77)* 1

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Safety helmets

The present invention relates to a polymer composite sandwich PCS safety helmet, where the safety helmet can be reduced in mass by up to 50%, without any concomitant loss in mechanical strength.

Conventional protective helmets available on the market today cover a wide spectrum of uses ranging from light uses for everyday wearing such as motorcycle or bicycle helmets, to professional use helmets such as those found in motorsport. Similarly the price of the helmets range from a few pounds for a bicycle helmet to several hundred thousand pounds (GB) for a Formula 1 racing car helmet. However light use and professional use helmets are made using the same basic two layer approach. The helmets are comprised of an inner layer which is typically a thick energy absorbing material, typically a foam, which will be placed adjacent to the wearers head and an outer layer, a shell which covers the foam, to provide a protective surface for the foam. The energy absorbing material is relatively stiff and brittle and would be uncomfortable for the user to wear therefore some form of comfort lining is usually required. The comfort lining can take the form of either; soft foams such as those found in bicycle and motorsports helmets, or a suspended lattice of fabric, commonly found in equestrian and cricket helmets and also flexible plastic mountings such as those found inside building site safety helmets.

Helmets which are constructed using the two layer approach typically have relatively high densities and relatively low overall stiffness. To ensure that safety standards for impact protection are met, the energy absorbing foam layer is typically very thick, in the order of several centimetres. As a consequence the helmet is displaced some distance from the wearers head, leading to an increase in the moment of inertia of the helmet in an accident. Further as the thickness and density of the foam increases, to satisfy the safety standards, so the mass of the helmet increases.

A conventional helmet works by dissipating the energy from the point impact over a large area of the energy absorbing foam, which will in turn reduce the total energy at the wearers head. Therefore it is desirable to increase the stiffness of the outer layer, to increase the dissipation of energy from the impact site across a larger area of the energy absorbing foam. Conventional helmet design has been advanced by the development of stiffer outer layers such as fibre reinforced plastics, e.g carbon fibre or aramid fibre, however these high performance materials can be prohibitively expensive for all but the top price range of safety helmet.

Helmets can be categorised into two distinct design shapes; re-entrant and non re-entrant helmets, a motorcycle helmet which attempts to encapsulate the entire head would be an example of a re-entrant shaped helmet. Whereas a non-re-entrant shaped helmet is essentially hemispherical, i.e. the open faced helmets, such as equestrian or bicycle helmets. It is well known that re-entrant shaped helmets provide additional manufacturing problems over the non re-entrant shaped helmets, which is reflected in the different methods used to construct the two types of helmet.

Further it is possible to categorize the helmet depending on the level of protection required. First there are manufactures who produce bespoke helmets for 'professional use', such as building site safety helmets, professional sports helmets i.e. for motorcar, motorcycle racing and even fighter jet helmets which require high level safety standards. Second, at the other end of the spectrum are manufactures who produce large numbers of 'light use' helmets for everyday use, such as bicycle, motorcycle, or equestrian helmets, which are produced at low cost which only need to achieve minimal safety standards. There are different safety standards required for 'light use' and 'professional use' helmets, and therefore are manufactured *via* different processes. This is also reflected in the large price difference between the different types of helmets. Therefore, it would be commercially advantageous to produce a helmet, which can satisfy both markets, that is, meet the safety requirements for 'professional use' helmets and yet be produced using high volume manufacturing techniques, to allow a high performance helmet to be produced at a competitive price for the light use market.

There are a number of desirable features, which should be considered when designing safety helmets in general, these include:

- must be lightweight and have a stiff outer impact shell,
- moment of inertia must be low, which is achieved by lowering the stand-off distance from the head, this in turn aids mass reduction,
- centre of gravity must positioned correctly,

- ~~should fit securely on the wearers head to prevent movement, especially during~~ an impact, and
- must be comfortable and continue to afford adequate impact protection.

Further it will also be desirable to have a means of fastening securely other items onto the helmet, such as a chin strap or visor, therefore during the moulding process suitable fastening positions may have to be incorporated into the design.

Safety helmets are designed to provide protection from different types of impact; high energy impact events, which result from accidents, and softer low energy impacts i.e. when the helmet is knocked by the user. It is therefore essential that the helmet can respond to both hazard types, because if the low energy impacts were neglected then permanent damage may occur to the high energy impact foam. Therefore it is usually desirable to fit a soft 'shape memory' foam to provide; protection from low energy impacts, and also to reduce 'jerk' (the rate of change of deceleration) during high energy impacts. The 'shape memory' nature of the soft foam means it can absorb small amounts of energy and recover to its original dimensions many times without degradation, unlike the high energy impact foam, which upon impact will deform irreversibly.

Sandwich core technology lends itself well to this type of low mass high strength application. A sandwich core will comprise a resilient material such as foam, which is sandwiched between two outer layers, which are typically hard and stiff. The sandwich core will provide a high level of stiffness compared to a conventional 2 layer approach, which allows the energy to be dissipated over a

~~larger area of resilient material and thus will decrease the energy at the users head.~~ It is known that for this type of structure that stiffness of the sandwich increases with the cube of the thickness of the sandwich. The sandwich structure can be produced from simple materials and when combined in a sandwich can have a stiffness value greater than modern high performance materials on their own.

However, there still remain a number of technical problems in producing sandwich core helmets using mass production techniques, especially if a high dimensional tolerance is also required. EP Patent 0650333 details the use of a sandwich type structure where an outer layer which is comprised of either a resin and fabric, or a pre-impregnated fabric, is placed in a female mould and pressed into place by hand, next the resilient layer and inner layer are loaded into the mould with hand pressing at each stage. The resilient material is defined as a flat sheet of either honeycomb, foam or cork. The problem with this method is that it requires each individual layer to be pressed by hand at each stage to ensure that it conforms correctly to the female mould, which is a time consuming process. A further problem arises when you press the flat sheet of foam under final consolidation pressure, as the foam will not conform properly to the mould shape and thus will decrease the dimensional tolerance of the finished helmet. Finally the consolidated helmet has to be finished, such as cutting out the opening for the visor.

FR Patent 2561877 describes the use of a sandwich type structure, which is limited to using a honeycombed resilient core to form the sandwich, again the resilient core material is loaded into the press in a flat sheet and so will encounter

~~the same manufacturing problems, as above. US Patent 4075717, describes the~~ manufacture of a safety helmet where an inner and outer layer are pre-formed, which are bonded together to form a hollow shell which is filled with a self expanding polymer. However, there are complications associated with this method from a manufacturing point of view, because the shell layers would have to be supported structurally during the EPS foaming process, adding an additional complex process step and giving rise to further manufacturing costs.

Advantageously, the inventor has found that the use of a pre-formed foam core in conjunction with appropriately selected inner and outer layers, allows for the mass production of safety helmets which are suitable for both 'professional use' and 'light use'. A further advantage is that it is possible to achieve a mass reduction of up to 50% compared to currently available light use helmets and at least a 30% mass reduction compared to certain current professional use helmets.

Further it shall be appreciated that in referring to re–entrant helmets or re-entrant motorsports helmets, which can be used in car driving, motorcycling, or other extreme sports, shall in the proceeding part of this description not preclude the use of the re-entrant shaped helmet for the average light user such as a motorcycle user.

It shall also be understood that the non re-entrant helmets are not limited to 'light use' ie bicycle helmets and can also be used for extreme sports such as hangliding, absailing, canoeing, cricket, equestrian, skating and even for medical helmets for people who are prone to collapsing such as epileptics.

Further the use of a pre-formed impact core can provide a high level of accuracy and dimensional tolerance, which is required for professional use helmets, compared to traditional polymer composite sandwich manufacturing techniques.

A further advantage is that the use of a pre-formed foam provides a template for the final shape of the inner layer, therefore allowing the inner and outer layer to have different surface attributes.

A still further advantage is that the use of a pre-formed foam allows the helmet to be formed without any significant finishing being required, such that for re-entrant shaped helmet the visor opening section is formed in-situ.

Accordingly it is an object of the present invention to provide a polymer composite sandwich safety helmet, which can meet the safety standards and dimensional tolerances required for professional users and can also be produced using mass manufacturing methods, to provide a low cost, lightweight safety helmet.

Accordingly the present invention provides a safety helmet comprising an outer substantially rigid polymer composite sandwich structure, and an optional inner comfort liner, wherein the composite structure further comprises

a first outer layer comprising a fibre reinforced polymer to form a hard outer surface, to the helmet,

a second layer of a pre-formed energy dispersive material,

~~a third inner layer comprising a fibre reinforced polymer, to form a hard inner~~ surface, wherein the first and third layers substantially encapsulate the second pre-formed layer,

wherein the three layers are bonded together.

The fibre reinforced polymer which comprise the first (outer) layer and third (inner) layer are produced from a plurality of layers of a strong fabric which are coated in a liquid curable resin. It is common practise to achieve the desired thickness of inner or outer layer, by laying alternate pieces of fabric orthogonal to each other as the weft and the weave have different strength characteristics, thus producing the maximum strength. The fabric can be any high strength fabric such as twill, carbon fibre, glass fibre or aramid fibre. It will be an obvious feature of the invention, that the outer and inner layers can be produced using either the same or different fabric materials, to achieve different mechanical and aesthetic properties.

The liquid resin which will form the hard surface of the polymer will be cured by either heat or UV. The resin may be chosen from polyester, polyurethane, epoxy, polybutylene, polyamide, which when cured provide strong, stiff and durable shells, preferably a polyester, polyurethane or epoxy resins are selected due to their good mechanical properties.

The inner and outer polymer layers may or may not be the same thickness, the outer layer will have a thickness in the range between 0.2-6.0mm and the inner layer will have a thickness between 0.2-3.0mm, the thickness of the layer will be

~~selected depending on the type of helmet and the associated safety standards that~~ need to be achieved. The selected thickness will however need to provide sufficient surface stiffness and strength and have a low mass.

In a preferred arrangement the outer layer is produced from at least two layers of fabric and the inner layer is produced from at least one layer of fabric. It will be obvious from the invention that at either one or both of the inner or outer layers can be produced from a fabric which is pre-impregnated with a curable resin, however an additional means of bonding may be required.

The second layer is a pre-formed energy dispersive material, which can be selected from a large number of resilient materials. The preferred materials are pre-formed expanded foams, which include polystyrene, polyethylene, polypropylene, polybutylene, polyvinylchloride or polymethacrylimide foam The energy dispersive foam is designed to withstand high energy impact events. The helmets final shape and size will be determined by the dimensions of the pre-formed foam liner. If the helmet is for a bespoke fitting for professional use, then the foam liner will be designed according to the wears head dimensions, alternatively if the helmet is to be mass produced then a range of common helmet sizes will be produced.

Typically the foams will have been expanded to a density in the range of 25-100kg/m^3, preferably in the range of 40-60kg/m^3. The foam core will have a thickness in the range of 5.0-25.0mm, preferably it will be in the range of 10.0-20.0mm.

In a first example it is preferable to use expanded polystyrene(EPS), due to its good impact properties and its ease of use and handling during most manufacturing techniques. However there is a compatibility problem, when using EPS and polyester resin together, in that they chemically react, thereby critically degrading the strength of the composite. Therefore it is desirable to apply an impervious barrier or membrane between the layers to prevent a chemical reaction. One such barrier would be an epoxy resin [which can also be used as the adhesive agent to bond the polymer composite sandwich together]. It is essential that the impervious barrier entirely covers the EPS foam, as any untreated areas will react with the polyester resin, therefore to ensure complete coverage its is desirable to add a spectroscopically active compound to the epoxy adhesive to monitor the application. The spectroscopic compound can be a coloured dye or a transition metal complex, which will ideally have its wavelength in the visible region. Other wavelengths in the UV or IR region can be selected, however they may be difficult to distinguish from the EPS and epoxy resin chemical spectra. It is to be understood that for mass production methods it may be desirable to use spectroscopic detectors to monitor the application of the epoxy. The epoxy can be applied to the foam core by a number of methods, including spraying, dipping or brushing, the method chosen depends on the type of production facility.

The preferred combinations of resin type and foam core are:

Polyester resin and an expanded polyurethane (PU) foam,

Epoxy resin and an expanded polystyrene foam,

~~Polyurethane resin and an expanded polystyrene foam, and~~

Polyester resin and an expanded polystyrene foam with an impervious epoxy barrier applied.

For non re-entrant shaped helmets the foam core can be located in the mould in one piece, as the mould is fully accessible. However, for re-entrant shaped helmets, the mould will have a small aperture diameter for the helmet opening, which is where the users head will fit through on the final article. Therefore the individual layers must be able to fit through this opening, to enable the loading of the pre-formed foam it is produced from at least three interconnecting pre-cast sections, which can be reassembled in situ. To prevent the foam core from moving in the mould, the abutting edges are chamfered to produce a locking engagement for the foam core within the mould. Further, it is desirable that for both non re-entrant and re-entrant foam cores, that the edges are chamfered or tapered to facilitate the encapsulation by the inner and outer layers.

The helmet will have a variety of sandwich structure profiles throughout the design. There will be areas, where the foam core will be completely encapsulated on all faces such as at the top of visor opening area. There will be areas where the sandwich has an open face, such that it is possible to see the discrete layers, such as at the vent holes or mounting holes, and further there will be regions where there is no foam and only resin, such as at some of the edges of the helmet. The sandwich structure whether it is open faced or totally encapsulated will have the same strength and stiffness properties.

The consolidation stage requires that the loaded mould be subjected to either positive or negative pressure and heated to at least 40°C for a duration of at least 5 minutes, to allow the resin to cure and form a strong adhesion to the impact core.

The type of press and the tooling required depends on whether the helmet has a re-entrant shape The tooling required for non re-entrant shaped helmets are relatively simple, as you only require a simple one piece mould and a corresponding mandrel to provide a means of consolidation. Whereas for a re-entrant shape, the consolidation tooling is more complex, with the requirements of a split mould and bladder type consolidation presses. It is also possible to use a vacuum forming process, for either helmet shape, such that the components are loaded into a female mould with a suitable former, which can be either a hard mandrel or a suitable high strength vacuum bag, the loaded mould and former are subjected to a vacuum and heated to at least 40°C to afford consolidation.

The consolidation stage must ensure that the cured resin and the impact core form a strong uniform structure. The stiffness and strength of the sandwich relies on the 3 layers acting as one material and not as three independent materials.

The next stage in processing the helmet is to ensure that the helmet is ready both functionally and aesthetically. This includes ensuring that edges of the helmet are finished to a high quality, by removing any excess material, from the sides of the helmet. The use of a pre-shaped pre-formed foam for the re-entrant shaped helmet

~~means that the space where the visor will be located is already formed, such that no~~ further cutting or processing is required, which potentially may give rise to structural weakness in the finished helmet. It may be desirable to place a finishing trim around certain edges of the helmet to provide an aesthetic finish. The mounting holes for the visor, chinstrap and other peripherals may be drilled or even pre-formed, and the relevant components fitted. Finally the venting plates need to be attached and any surface decoration such as transfers, paint or finishing fabrics, such as felt for equestrian helmets, can be applied.

The penultimate stage of the production of the helmet is to fit the inner comfort liner, which comprises a degree of 'shape memory', such that for small deformations the comfort liner will return to its original position, which will prevent the premature degradation of the polymer composite sandwich. The use of plastic and material lattices are well known in the field of helmet design and as such will be limited to non-re-entrant shaped helmets such building site, cricket and equestrian helmets. Re-entrant shaped helmets in general and some non re-entrant helmets, such as bicycle helmets, use low density foam to provide the necessary comfort lining. For re-entrant shaped helmets a close fit is required, which is best achieved by the use of foams, as it would be difficult to achieve a uniform lattice of material for a re-entrant shaped helmet. The comfort foam liner will usually be a soft expanded foam and may be selected from polystyrene, polyethylene, polypropylene, polybutylene, polyvinylchloride or polymethacrylimide, preferably EPS. The foam will have been expanded to a density in the range of from 25 to $100kg/m^3$. Further the foam will have a thickness in the range of 1mm to 30mm.

The final stage is to mount any required peripheral items onto the helmet, these include were applicable visors, chinstraps, lights, and reflectors. A further feature, which can be mounted on the helmet is a Head Mounted Display (HMD), due to the relative cost of the technology at present this is only likely to be incorporated onto a military fighter jet helmet, however it is possible that HMD's will be provided on motorsports helmets If an HMD is to be used, the helmet must possess a high degree of dimensional tolerance, as the helmet will act as an optical bench and thus stability and alignment of the helmet and the users eye-line are critical.

In a first embodiment the outer layer, inner layer and the impact foam core are each pre-formed in a separate manufacturing procedure, the three layers can be pre-assembled in the female mould before the final consolidation in the bladder press, this would significantly decrease the time for loading the mould. Advantages of this method are that the individual liners and foam inserts can be critically examined for inconsistencies such as cracks or blemishes before the final pressing procedure.

The invention relates to safety helmets although it is conceivable that the invention could be used for other types of protective garments either as pieces of padding or can be integral parts of larger garments, to protect a vulnerable area of the body such as the elbow, knee, thigh, shin, hand or foot, this list is not an

~~exhaustive list and only serves to highlight some of the other areas which may be~~ considered, when designing protective clothing.

The invention will now be described by way of a worked example for the manufacture of a re-entrant and a non re-entrant safety helmet.

Examples of re-entrant helmets which have been developed using this technology are motorsport and fighter jet helmets, which possess a means for attaching peripherals such as a visor and chin strap and the design must also incorporate vent holes to allow air to circulate inside the helmet and in the case of the jet fighter helmet the HMD has also been incorporated.

A typical method for the production of a re-entrant shaped helmets is described below.

The outer layer is formed by applying a portion of onto the surface of the female tool and laying the desired number of pieces of fabric into the resin. At least one piece of fabric will form the dome area of the helmet and at least one further piece of fabric will form the lower chin bar area, there will be at least two layers of material in the first outer layer, more may be required to produce the desired thickness.

The next stage of preparation is dependent on the selection of the material for the energy dispersive layer. If EPS is to be used as the pre-formed energy

~~dispersive layer it will need to be pre-treated with an impervious barrier, such as an~~ epoxy resin to prevent the polyester resin from chemically reacting with the EPS. Whereas, if an alternative foam is used for the impact core, such as polyurethane, no such impervious barrier will be required.

The energy dispersive material is constructed from three interconnecting pieces; a main, left and right piece, the main piece is placed into the female tool first and is located in place using the space where the air vent will be located on the helmet dome as a means of alignment. To prevent movement during the final pressing process the three interconnecting pieces each have a chamfer on their abutting edges so that when they are placed into the mould in the correct configuration they can be fixed into position. The inner layer is formed by applying a portion of resin onto the surface of the fixed impact core foam, and further laying at least one piece of fabric into the resin, to complete the laminate. The last stage is consolidation, for which the male bladder is inserted into the female tool. The mould is heated to approximately 40°C and a pressure of 1 bar applied to the bladder, for a duration of 5 to 10 minutes.

By way of an example only, the current in service specification for a fighter jet safety helmet has a mass of approximately 1.4 kg, whereas compared to a helmet produced by the above invention, constructed to meet the same safety and high dimensional tolerance requirements will have a mass of only 1.0 kg, this equates to at least a 28% reduction in mass. This reduction becomes significant when the pilot

undergoes a high 'g' manoeuvre, as this will greatly reduce the strain on the pilot's neck.

By way of a further example for a motorsports helmet, a typical helmet in the mass production market for a light user will have a mass between 1.4-2kg, even professional helmets such as Formula 1, have a mass of greater than 1.2kg, whereas compared to a safety helmet produced for motorsports by the current invention will have a mass in the range 700-1000 grams, which gives rise to a greater than 50% reduction in mass, for certain helmets, when compared to the equivalent mass production helmet.

By way of example non re-entrant helmets, may also be prepared according to the method of the invention, such as helmets for equestrian, cricket or even a building site safety helmet.

The invention will now be further described with reference to the accompanying drawings in which figures 1 to 4 represent the components of a re-entrant shaped helmet where:-

Figure 1 is a representation of the outer layer, which is produced from a 400gsm twill fabric and polyester resin

Figure 2 is a representation of the inner layer, which is produced from a 400gsm twill fabric and polyester resin

Figure 3 is a representation of the impact foam core, which is produced from an EPS material.

Figure 4 is a representation of inner comfort liner, which is produced from an EPS material.

Figure 1 is a representation of the outer fibre reinforced polymer layer, the female mould (not shown) will have a series of positive and negative embossments, which will produce the surface topography of the outer layer. The key features of the outer layer are the dome section which houses the top vent recess (1), and the forehead vent recess (2), which is also used as a means of aligning the impact foam core in the female mould. There is a further vent in the chin bar area (3), the vents (1, 2, 3) are designed to ensure sufficient air can circulate inside the finished helmet. The visor section (not shown) will be located in the cut out area (4) and will be secured and hinged at the respect anchorage points (6), which are located on both sides of the helmet. The chinstrap (not shown) will be secured at the attachment hole (5), with an identical fixing point located on the other side of the helmet (not shown). The attachment holes (5,6) are milled at the final helmet finishing stage, to ensure correct alignment.

Figure 2 is a representation of the inner fibre reinforced polymer layer. The impact core liner (as shown in figure 3) will behave as a female mould for the inner layer, the foam core will have a series of positive and negative embossments which will produce the final surface topography of the inner layer. The key features of the inner layer are similar to those of the outer layer, the dome section (11), the forehead vent recess (12) and a further vent on the chin bar area (13), which will align with the respective vents on the outer layer. The visor section (not shown) will be located in the cut out area (14) and will be secured and hinged at the respect anchorage points (16). The chin strap (not shown) will be secured at the attachment hole (15). The attachment holes (15, 16) may be milled at the final

helmet stage, to ensure correct alignment. After consolidation in the bladder press the comfort foam liner as shown in figure 4, will be bonded to the inside of the inner layer.

Figure 3 shows the second layer which is the pre-formed impact foam core. To facilitate the loading of the foam core into the mould it has been made from three interconnecting pieces, those being the main dome section (21), the left section (27) and the right section (28), these sections are aligned in the mould by using the forehead vent recess (22) as a reference point. To reduce the incidence of movement or slippage of the three interconnecting pieces the abutting edges are chamfered, additionally the external edges (29) are chamfered, to allow the inner and outer layers of the laminate to easily encase the impact foam core. Further the visor section (not shown) and the chin bar are not clearly defined as these areas will not utilise the sandwich core technology, however the respect anchorage points for the visor (26) and chin strap (25) are detailed on the foam core.

Figure 4 shows the profile of the inner comfort liner. The large dome area (31) contains a number of ventilation holes (33) to allow air to flow around the inside of the helmet, and further forehead vent hole (32), which will be aligned to the respective forehead vent holes (2, 12 and 22). The inner comfort liner will be secured to the main polymer composite sandwich in a separate bonding process, however to assist in the correct location of the of the inner liner there is a snap fit attachment point (35) which will locate with a corresponding lug on the inner layer (not shown).

Claims

1. A safety helmet comprising an outer substantially rigid polymer composite sandwich structure, and an optional inner comfort liner, wherein the composite structure further comprises
a first outer layer comprising a fibre reinforced polymer to form a hard outer surface, to the helmet,
a second layer of a pre-formed energy dispersive material,
a third inner layer comprising a fibre reinforced polymer, to form a hard inner surface, wherein the first and third layers substantially encapsulate the second pre-formed layer,
wherein the three layers are bonded together.

2. A helmet as claimed in claim 1, wherein the first layer, fibre reinforced polymer is produced to a thickness in the range of 0.2mm to 6mm, preferably 0.5 mm to 2.5mm.

3. A helmet as claimed in claim 1, wherein the third layer, fibre reinforced polymer is produced to a thickness in the range of 0.2mm to 3mm, preferably 0.2 mm to 1.5mm.

4. A helmet as claimed in any of the preceding claims, wherein the fibre reinforced polymer comprises a curable resin which encapsulates a plurality of layers of fabric.

5. A helmet as claimed in claim 4, wherein the alternate layers of fabric have an orthogonal relationship to each other.

6. A helmet as claimed in claim 5, wherein the fabric is selected from twill, carbon fibre, glass fibre or aramid fibre.

7. ~~A helmet as claimed in any of the preceding claims wherein the resin is selected~~ from an epoxy, polyester, polyurethane, polybutylene or polypropylene.

8. A helmet as claimed in any of the preceding claims, wherein the pre-formed energy dispersive material, is an impact foam selected from a pre-formed expanded; polystyrene, polyethylene, polypropylene, polybutylene, polyvinylchloride or polymethacrylimide foam.

9. A helmet as claimed in claim 8 wherein the thickness of the impact foam is in the range of from 3 mm to 25 mm.

10. A helmet as claimed in claim 9 wherein the thickness of the impact foam is in the range of from 10 mm to 20 mm.

11. A helmet as claimed in any of the preceding claims, wherein the comfort foam liner is selected from an expanded; polystyrene, polyethylene, polypropylene, polybutylene, polyvinylchloride or polymethacrylimide foam.

12. A helmet as claimed in any one of claims 7 to 11 wherein the foam has a density in the range of 25 to $100kgm^{-3}$.

13. A helmet as claimed in claim 12 wherein the foam has a density in the range of from 40 to $60kgm^{-3}$.

14. A safety helmet comprising an outer substantially rigid polymer composite sandwich structure, and an optional inner comfort liner, wherein the composite structure further comprises

a first outer layer comprising a fibre reinforced polymer to form a hard outer surface, to the helmet,

a second layer of a pre-formed energy dispersive material, is formed from at least three interconnecting pre-cast sections, wherein the abutting edges are chamfered to produce a means of locking engagement for the sections,

~~a third inner layer comprising a fibre reinforced polymer, to form a hard inner~~ surface, wherein the first and third layers substantially encapsulate the second pre-formed layer,

wherein the three layers are bonded together.

15. A helmet as claimed in any of the above claims wherein the preferred combinations of inner/outer layer resin and impact foam are
Polyester resin and polyurethane foam impact core,
Epoxy resin and expanded polystyrene foam impact core,
Polyurethane resin and expanded polystyrene foam impact core,
Polyester resin and expanded polystyrene foam impact core.

16. A helmet as claimed in any one of the preceding claims, wherein the helmet is substantially re-entrant in shape.

17. A helmet as claimed as claimed in any one of claims 1 to 14 wherein a polyester resin and expanded polystyrene foam impact core are selected, and a uniform impervious barrier is applied between the layers to prevent a chemical reaction.

18. A helmet as claimed in claim 17 wherein the uniform impervious barrier contains a spectroscopically active compound to monitor the application.

19. A helmet as claimed in either of claims 17 or 18 wherein the uniform impervious barrier is applied to the foam by means of spraying, dipping or brushing.

20. A helmet as claimed in claim 19, wherein the uniform impervious barrier is an ~~epoxy adhesive.~~

21. A helmet as claimed in claim 20 wherein the epoxy is applied to the foam by means of brushing.

~~22. A safety helmet as claimed in any of the preceding claims, wherein the helmet,~~ incorporates mountings for at least one of the following, chin strap, visor, illumination unit, reflector or head mounted display.

23. A safety helmet as claimed in any one of the preceding claims wherein the helmet is used as a bicycle, motorsports, building site, equestrian, cricket, medical or fighter jet safety helmet.

24. A safety helmet as claimed in claim 23, wherein the fighter jet safety helmet has a mass in the range of from 700 to 1200 grams.

25. A safety helmet as claimed in claim 24, wherein the fighter jet safety helmet has a mass in the range of from 900 to 1000 grams.

26. A safety helmet as claimed in claim 23, wherein the motorsports helmet has a mass in the range of from 700 to 1200 grams.

27. A safety helmet as claimed in claim 23, wherein the motorsports helmet has a mass in the range in the range of from 900 to 1000 grams.

28. A process for the production of a safety helmet comprising an energy dispersive polymer composite sandwich structure, which comprises laying into a female mould an outer layer of a fibre reinforced polymer, a second layer of a pre-formed energy dispersive material, and a third inner layer, wherein the first and third layers substantially encapsulate the second pre-formed layer, wherein the three layers are bonded together.

29. A process according to claim 28, wherein the first and third layers are substantially the same.

30. ~~A process according to claim 28, wherein the second pre-formed energy~~ dispersive material layer is produced from a resilient material as claimed in claim 8

31. A process for the production of a safety helmet comprising an energy dispersive polymer composite sandwich structure, which comprises laying into a female mould an outer layer of fabric and polyester resin, an impervious epoxy barrier, a second layer of a pre-formed expanded polystyrene foam, an impervious epoxy barrier and a third inner layer of fabric and polyester resin, wherein the first and third layers substantially encapsulate the second pre-formed layer, wherein the three layers are bonded together.

Abstract

A low mass safety helmet is provided, containing a sandwich of polymer composite materials to produce an effective means of shock mitigation to a wearer's head. The sandwich comprises an inner and outer layer of fibre reinforced polymer which encapsulates a pre-formed energy dispersive material which is typically a high impact resistant foam. Optionally, on the inside surface of the inner layer which is adjacent to the wearer's head there may also be fitted a comfort liner, manufactured from either a low density impact foam or a material or plastic lattice, to provide comfort to the wearer and protection from low energy impacts. The use of a pre-formed foam liner in the manufacturing of the helmet allows for accurate dimensional tolerances to be achieved, thus allowing helmets which can meet the requirements for both military and civilian use to be manufactured by mass production techniques.

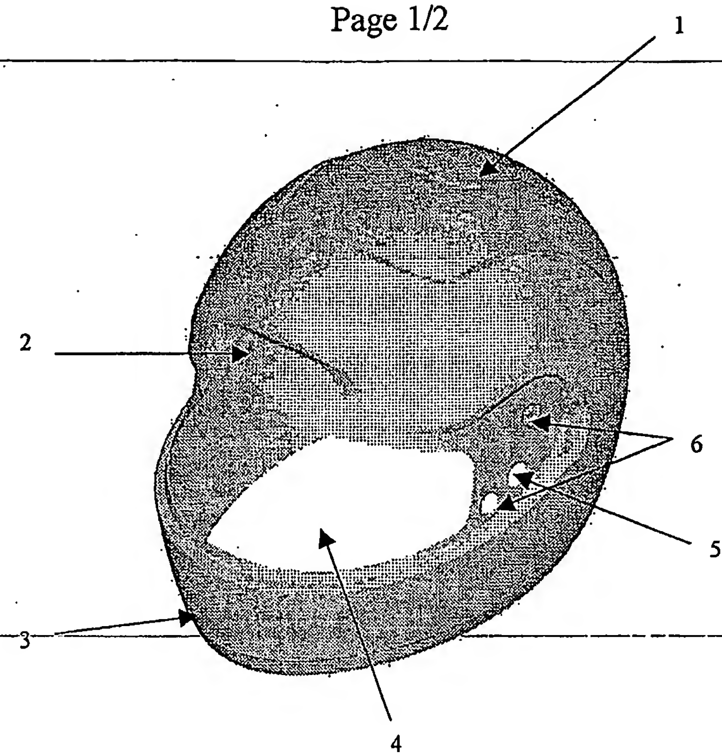

Figure 1

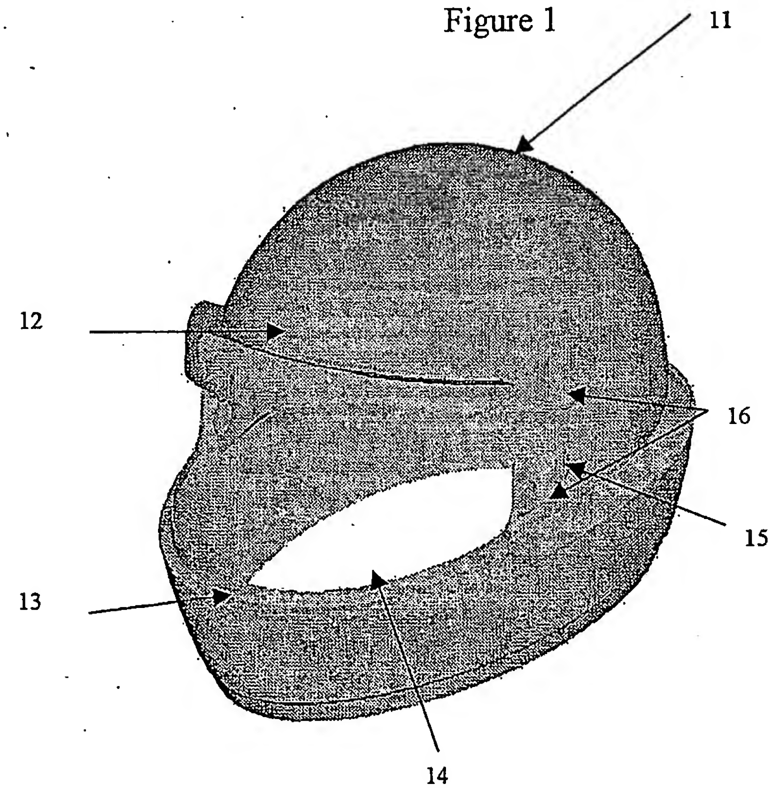

Figure 2

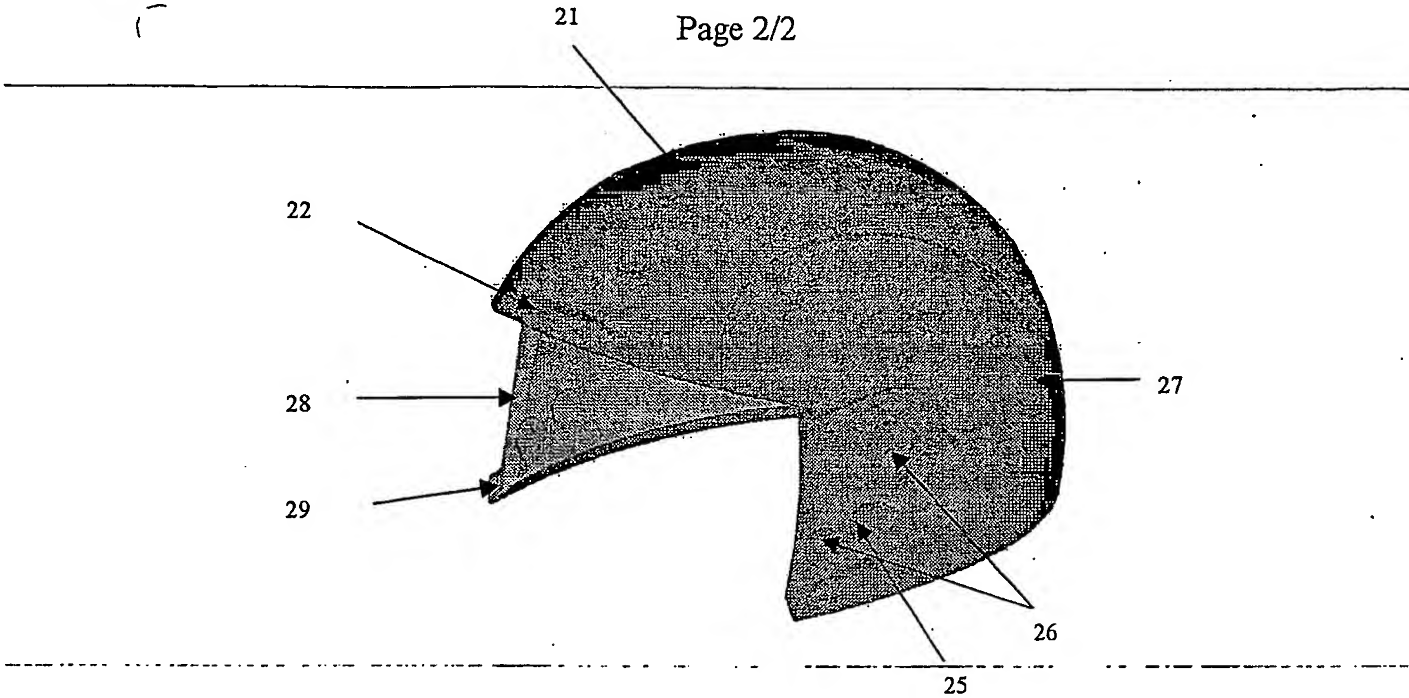

Figure 3

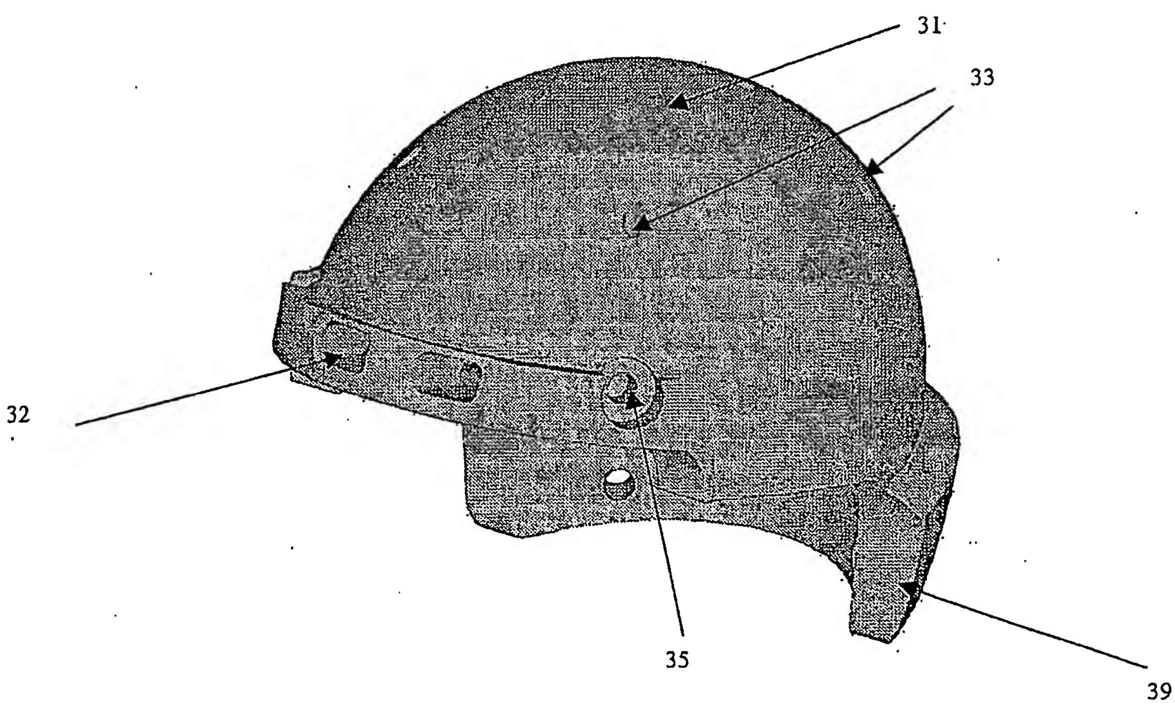

Figure 4

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